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Issue Paper I

STRATEGIES OF DEVELOPMENT AND FINANCIAL IMPLICATIONS ON THE NON-FERROUS METALS INDUSTRY*

Prepared by

the UNIDO Secretariat

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1. Introduction

In several developing countries the development of the non-ferrous metals sector has not significantly contributed to the process of creating at the national and regional levels, a more coherent productive system thereby leading to the development of adequate linkages with the other sectors of the economy as well as complementarities among countries of the same subregion or region. In some developing countries large investments were concentrated on mining and metallurgical activities affecting the development of other vital sectors of the economy such as the agricultural sector, leading to the need to import food. Moreover, these efforts in investment in the non-ferrous metals sector made by some developing countries were not compensated by an adequate surplus of foreign currency due in many cases to the deterioration of prices and the non-favourable evolution of the consumption of most of the traditional non-ferrous metals.

The limited economic results obtained by several important mining and metallurgical developing countries calls for the need to search for strategies of development for the different non-ferrous metals industries that would have a greater impact on creating a more integrated development, satisfying the basic needs of the population and increasing the surplus of foreign currency.

In the selection of the strategies of development and of concrete projects, developing countries must take due account of the new patterns of investment and finance that are taking place in the non-ferrous sector in order that the strategies and projects developed are viable. This is necessary owing to the fact that the traditional sources of investment and finance of the 1970's, (i.e. the transnational corporations and commercial banks) have decreased their participation in the non-ferrous sectors during the present decade in many developing countries. To this can be added the financial constraints of many deve oping countries due to the debt problem and the decline of prices and consumption of non-ferrous metal products on the world market.

2. The evolution of the non-ferrous metals industry

The evolution of the non-ferrous metals sector has been affected by the structural changes which took place in the world economy in the 1970s, as well as by the economic recession, which mainly struck branches that have traditionally been among the most important consumers of non-ferrous metals.

The structural changes that have taken place in the world economy have had different effects on the various non-ferrous metals. Thus, we find that in the United States of America and Japan there has been a sharp increase in the consumption of those non-ferrous metals that are associated with the so-called "advanced" sectors, e.g., electronics, the nuclear industry and the aeronautical industry. During the 1970s in the United States, the annual consumption of tantalum increased by 19.5 percent, of berylium by 11.9 percent, of zirconium by 8.0 percent, of silicon by 6.9 percent, of titanium by 6.2 percent and of lithium by 5.2 percent. In Japan during the same period, tantalum consumption increased at an annual rate of 13.6 percent, titanium consumption at 12.9 percent, lithium consumption at 11.7 percent, silicon consumption at 10.3 percent and zirconium consumption at 8.4 percent 1/.

From 1970 to 1980, the evolution in the so-called traditional non-ferrous metals was seriously affected by fluctuations in the world economy, and their rates of growth were much lower than the non-ferrous metals linked with the so-called "advanced" sectors. The increase in annual consumption of primary aluminium world-wide during 1970-1980 was of 5.3 percent, of refined copper 2.9 percent, of refined tin 0.2 percent, of refined nickel 2.4 percent, of zinc lingotes 2.1 percent, and of refined lead 3.8 percent.

In the early 1980s, there was an increase in the levels of stocks of traditional non-ferrous metals partly due to the tendency of several manufacturers to maintain relatively high production levels because of their urgent need for foreign exchange with which to meet their financial obligations and pay for imported goods and services. The prices of those non-ferrous metals fell in 1981 and 1982. For many of the so-called traditional non-ferrous metals the real prices in 1982 were the lowest for the preceding three decades and were in fact below the costs of many producers.

During the period subsequent to 1982, which showed an acceleration in world economic growth rates, there was a relatively modest movement in the non-ferrous metals sector as a consequence of the strucutral changes affecting the world economy and especially the principal industries using those metals. Thus, we find that consumption levels during the period 1983-1986 were very similar to, and in the case of tin, lower than those recorded before 1983. In the case of copper, the world consumption level reached in 1985 was slightly higher than that of 1981 and below the 1979 level. With respect to copper consumption in market-economy countries after the bad performance in 1982 and 1983, since 1984 it seems to have hold a steady pattern. As for tin, consumption in 1985 in the market-economy countries was below that of 1981 and substantially below that metal's maximum consumption level recorded in 1973.

1/ Pierre-Nöel Giraud. "Geopolitique des Ressources Minières", Economica, Paris, 1983, pp. 326-327.

As regards aluminium, there was an increase of some significance in its consumption following 1982. World aluminium consumption in 1984 was greater than that achieved in the ealier years of the 1980s, but below the 1979 level. Consumption in the market-economy countries in 1985 was slightly higher than the maximum consumption recorded in 1979.

Due to the modest increases in consumption as well as the high inventory levels which peaked in 1982, producers tended to maintain relatively low production levels in order to improve their prices. For copper, production levels both world-wide and in the market-economy countries, were below consumption. The tendency of the copper producers, beginning in 1982, to maintain levels of production lower than those of consumption led to a sizeable decline in their inventories and to an improvement in their price levels. As for tin, beginning in 1983 production was below consumption, but commercial inventory levels have not been able to be reduced; on the contrary, the inventory level for 1985 was above that of 1982 and the price level during the first months of 1986 was far below the prices of the preceeding years. Since 1982, in the case of alumunium, one finds the same tendency, to maintain production levels below those of consumption that has caused a reduction in the level of inventories, without, however, exerting any favourable effect on the price level, and following a significant increase in 1983, the trend in subsequent years has been downward. Some improvements of the alumina price could be observed in the first five months of 1987.

The adjustments which the producers have been making for the purpose of bringing their production capacity into line with consumption and price levels have led, on the one hand, to major reductions in the production capacity through the closing of plants and, on the other, to the cancellation or deferral of new projects, as well as to the tendency to relocate or establish new production capacities only in countries offering very favourable conditions with respect to the abundance of ore and the cost of energy.

However, it should be noted that recently, due to some improvement in prices and tightness in metal supply, North America was prompting several aluminium companies to re-open some of their idled potlines. Among these one should mention Alcan's, Sebree smelter and Alco's Warrick and Badin. Reynolds Metals also announced their intention to re-start their potline at Troutdale 2/. It was also announced that with improvement of markets for aluminium, Alcan is resuming work at its Laterriere primary smelter, and according to the company's recent announcement, metal from the first 50.-50.000 tpy capacity should be coming by the end of 1989 3/.

2/ Metal Bulletin, 23 June 1987, p.7
3/ Metal Bulletin, 19 May 1987, p.11.

3. The principal agents and their role

Governments of developing countries have found themselves in the predicament of, on the one hand, having to deal with the urgent need to increase their exports of non-ferrous ores and metals over a short term so as to generate the foreign exchange required for the normal operation of their economies, and, on the other, of wanting to introduce measures aimed at achieving structural and operational changes in their mining and metallurgical activities in order to overcome their increasingly deteriorating situation.

In order to cope with this new situation, Governments of developing countries have in different ways increased their participation, either directly or indirectly, in their mining and metallurgical sectors.

A number of Governments, anxious to prevent any reduction in the revenue generated through these activities, have taken over some operations of transnational enterprises. Thus, for example, the Government of Jamaica assumed control over the Alcoa-owned Clarendon refinery for a period of two years from July 1985. The explanation given in this case was that Alcoa intended to close down the plant because of marketing and production cost problems. On the other hand, other Governments have favoured barter agreements, such as the one concluded in 1985 between the Government of Guyana and the Soviet Union, under which the former has undertaken to export bauxite to the Soviet Union in exchange for machinery and pharmaceutical products. Similarly, the Government of Suriname has entered into an agreement with Czechoslovakia whereby in exchange for manufactured goods from that country, Suriname is to supply bauxite covering up to 30 per cent of their value, with the remaining 70 per cent to be covered in the form of letters of credit.

Governments of developing countries are also promoting South-South co-operation agreements. One such example is the agreement concluded between Brazil and Suriname, under which the former has undertaken to extend a line of credit worth US$20 million to Suriname in exchange for alumina. Another example is the recent contract to produce copper tube for the Chinese market under a new joint venture called Beijing-Santiago Copper Tube Company. This Chilean-Chinese joint venture is expected to construct a plant in Beijing within the next two years with a capacity of 10 - 15,000 tons per year [4/]. Also Thailand PADAENG zinc smelter, which started up in 1985, has an important programme for export mainly directed at the countries of the region, China, South Korea and the Philippines [5/].

For the purpose of improving the efficiency and profitability of their operations, a number of State-run enterprises have concluded technical assistance agreements with transnational corporations. The State-operated enterprise Bauxite Industry Development Company (BIDCO) of Guyana signed a five-year agreement with Reynolds under which the latter is to provide it with technical assistance until the year 1989.

With a view to increasing their exports of non-ferrous ores and metals over the medium and long term, a number of Governments are formulating and implementing joint projects involving foreign capital: Japan and Brazil are

4/ Metal Bulletin, 24 March 1987, p. 8
5/ Metal Bulletin, 2 September 1986, p. 9.

jointly engaged in building a smelter at Vila de Conde; Ecuador and Belgium are exploring for copper and molybdenum in the North-east of Ecuador. Papua New Guinea's OK Tedi Mining has recently reached a 5-year agreement to supply copper concentrate to a Japanese consortium of 7 smelters. Further contracts have been signed with Korea Mining and Smelting and with the Norddeutsche Affinerie 6/.

The Governments of certain developing countries are conducting negotiations with transnational enterprises with a view to retaining or improving the taxation and legal arrangements that guarantee them acceptable levels of revenue from their exports at a time when their negotiating position has been weakened by the situation on the world market for non-ferrous ores and metals. The Government of Guinea has been engaged in negotiations on export tax schedules with the Compagnie des Bauxites de Guinee (CBG); any loss in the amount paid per export ton would place the country in a difficult economic and financial situation, since bauxite and alumina exports generate about 93 per cent of Guinea's foreign exchange revenue 7/. In addition, there might be repercussions on the other aluminium-exporting developing countries in their future negotiations with the transnational enterprises.

In the light of the results achieved to date in their mining and metallurgical activities, certain developing countries are promoting new forms of development for the purpose of increasing the impact of the non-ferrous metals sector on their economies. Governments are analysing the possibilities and advantages of promoting a more extensive vertical integration of the non-ferrous metals industries for the purpose of increasing the national value added to their exports, as well as of achieving greater diversification in their production. They are having studies prepared on the feasibility of increasing production of the minor metals found in the ores of the heavy non-ferrous varieties. What is more, questions are being raised about the essentially outward-oriented development policy that has been pursued by the non-ferrous metals sector for the primary objective of earning foreign exchange. As part of this questioning, the view has been put forward that the growth of this sector should be promoted in a way so as to establish more coherent production structures at the national and regional levels by building closer linkages between the non-ferrous metals industries and the other sectors of the economy. Nevertheless, it is important to note that the large majority of developing countries have no medium- or long-term plans for the development of the non-ferrous metals sector.

The transnational enterprises have been adopting a fairly cautious approach to new investments. Moreover, they are redirecting these investments. It is generally fair to say that there is a tendency to favour the new investments mainly in Australia, Canada and certain Latin American countries and to some degree, Guinea.

6/ Metal Bulletin, 24 March 1987

7/ Guinea plans to reduce its dependence on bauxite revenues by diversifying its mining production and putting emphasis on the development of agriculture to reduce food imports. (Metal Bulletin, 7 October 1986, p. 19).

These transnationals have gradually tended to focus their activities on the final phases of the manufacturing process, such as production of semi-finished products, and to place less emphasis on primary operations. The principal reason for this is to be found in the fact that the logic underlying the price-setting process in recent years has generally benefited the final-phase products by pricing them at a higher level. Thus we find, for example, that the prices for aluminium ingots have remained relatively independent of those charged for semi-finished products; when ingot prices were low, semi-finished items were selling at relatively high levels. The transnational enterprises have also, in their research and development programmes, tended to accord priority to the production phase for semi-finished and other products 8/.

Governments of developed countries are also following with interest operations of non-ferrous metallurgy. The Canadian Government authorities have agreed to provide a 14 million Canadian dollars loan without interest to Noranda's GASPE Mines to help with the reopening of that copper mine 9/. The United Kingdom granted a £25 million loan package to keep Rio Tinto-Zinc's South Crofty and Wheal Jane mining operating. The money will be spent on modernizing the facilities in order to lower production costs 10/.

The non-ferrous metals producers are promoting new associations or institutions that will provide them with greater guarantees in their operations despite the collapse of the ITC price protection system for tin and the modest results achieved by the IBA in recommending minimum prices for bauxite and alumina for 1985.

At the initiative of the North American nickel producers, a Nickel Development Institute (NIDI) has been established for the purpose of identifying new applications and markets and carrying out further research and development studies. Similarly, in 1985, Canada, Japan and the United States proposed the creation of an international copper study group, involving the participation of Governments and experts, with a view to achieving greater market transparency and promoting a better understanding between the various agents active in this area.

8/ It should be noted that while there is a general trend with the big transnationals to focus their attention on the final phases of the metallurgical process, such as production of semis, ALCAN remains committed to being a net seller of aluminium ingot with sales at about 25 percent of its production capacity. (Metal Bulletin 23 June 1987, p. 7).

9/ Metal Bulletin, 19 May 1987, p. 9

10/ Engineering and Mining Journal, March 1987, p. 67.

4. The industrialization process and the non-ferrous metals

4.1 Some remarks related to the development of the mining and metallurgical sector

The developing countries that produce non-ferrous ores and metals exhibit different production characteristics as well as dissimilar prospects and strategies. In a number of developing countries, the production of non-ferrous metals is essential to the normal operation of the national economy, given that the export of their ores or metals is the principal source of their foreign exchange. In other developing countries, although the impact of the non-ferrous metal sector is at this time not significant, the role of this sector in the economy is expected to increase substantially in the future.

For some developing countries which are producers, the prospects for the future expansion of this sector are dim for the reason that the particular metals they produce, such as tin, are critically depressed thoughout the world. Conversely, in other countries, the outlook is more favourable because of the type, quality and abundance of their mineral resources, their relatively low extraction, processing and energy costs, and the high level of integration that exists between the non-ferrous ore and metals sector and the rest of the economy. Some developing countries of this kind have embarked on ambitious investment programmes.

Neither the production structure characteristics nor the development strategies of these countries are everywhere the same. There is a number of producers who have concentrated mainly on the extraction phase, whereas others have achieved a higher degree of processing and vertical integration. Similarly, the extent to which the non-ferrous metals sector is linked with the rest of the economy also differs. In some cases, this sector is virtually an enclave with few links to the other sectors of the economy, its output being intended primarily for export, while in other non-ferrous metal-producing countries this sector has developed linkages of some significance with the other sectors of the economy, so that it has become not only a source of foreign exchange revenue, but also a vehicle of internal development.

However, despite the diversity that distinguishes them, most of the developing countries that produce non-ferrous ores and metals have pursued an outward-diected growth. Mining and metallurgical activities were conceived and built up for the main purpose of achieving rising levels of exports, with the ultimate aim of becoming major sources of foreign exchange to import the capital goods and other products their economies require.

In its various forms, this export-based development pattern has in several cases not achieved positive results from the economic, financial and social standpoints. In some cases, this has been independent of the extent of processing to which the exported products are subject: a higher level of processing for ores and/or metals does not necessarily guarantee a better foreign exchange balance, despite the higher unit price

commanded by the export product. This is due, in many cases, to the need for more extensive intermediate imports and of a significant level of indebtedness in order to create the new production capacity [11]. Very often, the additional value added so generated is absorbed by overcharges in the purchase of equipment, the payment of royalties for the acquisition of the technology and the high interest rate on the loans received. What this means is that there is no automatic cause-effect relationship between more extensively processed export products and greater foreign exchange revenue, on the one hand, and better economic and financial performance, on the other; this relationship will depend on the economic calculation for each specific situation [12].

Apart from the limited economic and financial results achieved by the mining developing countries in general, and in the non-ferrous ores and metals sector in particular [13], developing countries are also suffering major structural constraints over which they have no control and which is expressed in a world-wide downward trend in the consumption levels of traditional non-ferrous metals and in a general decline in prices. On the other hand, the favourable natural conditions of some developing countries can represent a possibility for them to strengthen their position in the international market and also to increase their vertical structure by giving more attention to the final phases of the manufacturing process, taking into consideration not only the foreign demand but also the domestic demand. All this calls for the need for a detailed analysis of the past experiences of development and for the search of alternative strategies of development.

11/ John M. Rothgeb of Boston University in his article "Investment Penetration in Manufacturing and Extraction and External Public Debt in Third World States", published in World Development, Vol. 12, No.11/12, pp. 1063-1075, 1984, makes the point that in Latin America there is no direct relationship between investment in extraction and the increase in the debt, while investment in manufacturing is closely related to this increase.

12/ Pierre-Nöel Giraud in "Geopolitique des Ressources Minières", Economica, Paris, 1983, pp. 677-690, compares the foreign exchange balances of the Guinean enterprises CBG and Friguia, both of which export all their output, the first as ore and the second in processed form. His analysis shows that the relation of the foreign exchange balance to the exports of CBG is higher than that of Friguia. The basic reason presented was the relatively heavy-weighted costs for the imported inputs required for the processing of bauxite by the Friguia enterprise.

13/ Ibid, pp. 652-653.

4.2 Alternative strategies: some relevant aspects to be considered

The development of the mining and metallurgical sector in the developing countries cannot be conceived separately from the development of the industrial sector and the economy of the country. Until now, in the majority of developing countries the development of this sector has been pursued as part of a process of export promotion and/or of an indiscriminate import-substitution process to answer to an imported structure of consumption. Few countries have envisaged the development of their mining and metallurgical sector in the context of a development policy based on creating a national and regional coherent productive system and on the satisfaction of the essential needs of the population by improving the relation between the agricultural, construction and industrial sectors.

In the light of these observations, the mining and metallurgical sectors may be seen to perform different economic functions in the different developing countries. On the one hand, the extraction and processing of non-ferrous metals may be intended to provide mainly the goods used as basic inputs for internal production; or on the other, these metals may be intended basically for export, thus exerting only an indirect effect on domestic industrialization. This indirect effect will depend on the degree of processing, the product type and the country's existing industrial infrastructure.

This indirect impact on the industrialization process may be generated through the supply of inputs to the non-ferrous sector from the various sectors of the economy on the basis of a selective import-substitution process and, similarly, through the financing of the imported products the country requires for its normal operation, as well as through the direct and indirect creation of employment.

4.2.1 Inward-oriented development for a more integrated development at the national and regional levels

The aim of a more inward-oriented pattern for the development of the mining and non-ferrous metals industry is to strengthen the ties between this industry and the capital goods sector, the main purpose being to provide a basis for the production of machinery, equipment and inputs needed to increase the production and productivity of the agricultural and contruction sectors. Moreover, such a pattern must strengthen the linkages between the mining and metallurgical sector with the transport and energy sectors by providing them with the essential inputs they require.

In order to accomplish this, there is need for a reliable identification of the non-ferrous metal products to be manufactured in an organized and co-ordinated manner in the various developing countries; giving special emphasis to the fabrication of semis and finished non-ferrous products that can be produced in a flexible way in small and medium-sized enterprises [14/]. This in turn requires the preparation of technical and economic studies on the specifications of the non-ferrous metal products required for the capital goods and other products whose domestic manufacture is to be promoted. The range of non-ferrous metal products to be produced in the various developing countries will depend largely on their production characteristics and on their physical and technical infrastructural assets. This is to say that the role which the non-ferrous metals sector should play in the industrialization process, as well as the pattern to be imparted to its linkages with the rest of the economy, will vary from one country to another or from one group of countries to another.

The effective implementation of a predominant inward-oriented development pattern for the non-ferrous metals sector in the developing countries requires a detailed analysis of certain key aspects in order to prevent them from emerging as major constraints to the achievement of this policy. Among these aspects, special mention should be made of the limited economic space of the developing countries, the nature of the technology to be adopted and the price levels and structure prevailing on the world market.

Given the existing pattern of imported technologies and the levels and structure of world prices, the manufacture for internal consumption of specific non-ferrous metal products in developing countries with limited markets is difficult to implement in an extensive manner.

In order to overcome some of these obstacles, the developing countries should promote regional or subregional co-operation through the formulation of complementary programmes. These programmes should indicate the time required for their implementation and state exactly where the production units are to be located so that a balanced development that will avoid the creation of disparities among the various countries participating in the programme will be possible.

It is also of great importance that developing countries select technologies, appropriate to their internal markets, and make more effective use of their resources. This requires that these countries make a significant effort in the area of technological research so as to avoid merely replicating the advanced technologies being developed in the industrialized countries. The focus should be on the design of technologies geared to their genuine requirements.

14/ For further details see Issue 2.

In order to achieve this, it is very often necessary to "disassemble" the imported technology packages and to "reassemble" them in accordance with the specific needs of the developing countries. Similarly, this effort of technology creation and/or transformation requires that account be taken of the technological advances that have occurred in other sectors. In steelmaking, which has always been regarded as an industry consisting of large-scale enterprises and where economies of scale are one of the most important productivity factors, the current trend is increasingly towards the erection of mini-plants with productivity levels very close to, and in some cases (for specific products) higher than, those of the gigantic iron and steel plant based on the blast furnace.

Many developing countries are frequently unable to promote the production of specific non-ferrous metal items necessary for the establishment of a more coherently productive system at the national or regional level because of the fact that the price structure prevailing in the world market and the country's internal production costs make this impossible.

Developing countries that decide to promote a more inward-oriented development, can, if they consider appropriate, set prices that permit them to organize their resources in such a way as to satisfy their principal requirements. What this means is that these countries should employ an economic calculus in the establishment of their production capacities, based on the most rational use of their internal resources; the concrete needs of the majority of the population; and in the optimal use of internal surpluses consistent with the constraints imposed by cost levels. World prices should be taken mainly as a yardstick or reference, and not as an externally imposed factor in the economic calculations of many of the developing countries.

4.2.2 Development of non-ferrous metals for export

The key concept underlying this outward-oriented development pattern is the increasing need on the part of the developing countries for foreign exchange with which to import the inputs and machinery required by their various economic sectors for their development. There also exists within this strategy the nearly universal notion that the higher the degree of processing incorporated in the products exported, the greater will be the net foreign exchange revenue and, accordingly, the more substantial its indirect impact on the economy as a whole. However, as has already been pointed out, there is no automatic relationship between more extensive processing for exports and better economic and financial results, for the reason that the latter depend in large measure on the country's concrete situation and on the nature of its production.

One of the alternatives within this pattern for the development of the mining and metallurgical sector is the export of ore in its crude state principally for the purpose of obtaining food products with which to cover the population's nutritional deficit, as well as the inputs, machinery and equipment for those sectors regarded as having priority importance.

A developing country with an abundance of non-ferrous ores could activate its agriculture for basic consumption by paying for its imported

equipment, fertilizers and pesticides through export of these ores. A development policy of this kind will be economically justified if, at the world market price, the ore exports can generate the internal surpluses required for financing the imports needed for agriculture without tapping non-renewable ore reserves. In this case, the economic calculation will be based on the establishment of a relationship between the volume of ore exported and the rate at which internal surpluses can be generated.

Another development alternative involves the export of non-ferrous metals to the world market at various degrees of processing. This can be an economically and financially sound alternative, given the structure of world prices, provided the developing countries that adopt this strategy have access to rich mineral ore reserves and energy at lower costs than the developed nations so as to offset the generally higher cost of the machinery and equipment they import. Moreover, the major investment effort required for this alternative should result in significant supplementary value added and in a positive and fairly substantial net foreign exchange balance.

Within this alternative there are different variants of vertical and horizontal integration. There are countries that have tended to favour vertical integration, with the mine as the point of departure, and for which the export of refined products has been the preferred approach. Conversely, there are others that have accorded priority to the production and export of semi-finished products based on imported inputs that have subsequently pursued a policy of backward integration.

With respect to horizontal integration, we find that a number of countries that initially earmarked their total production for export have subsequently channelled a portion of this production to internal consumption, in addition to promoting the procurement of inputs from national industry. This has given rise to a closer set of linkages between the non-ferrous metals sector and the rest of the economy. Other countries export virtually all their production and import a large part of the inputs and equipment they require, so that the non-ferrous metals sector represents a kind of enclave within the economy.

Production intended principally for export requires technology that is competitive at the world level, as well as marketing channels to guarantee the sale of the products. These factors have led to a major involvement of foreign capital in the development of export-oriented non-ferrous metals sectors. The level of this involvement differs from one country to another and depends on the type of products in question. In some developing countries, this sector has been promoted mainly through direct investments by transnational companies that are the main owners of the enterprises created. In other countries, joint ventures have been established, in which the State and national private sector share ownership with the transnational companies. With this approach, foreign loans often play a larger role in the establishment of the new production capacities than direct investment. There are also countries in which the enterprises are owned by the State, but in certain circumstances enter into technical assistance and marketing contracts with the transnational companies.

The export of non-ferrous ores and metals for the indiscriminate import of luxury goods and the creation of an industry essentially limited to assembly operations will not be economically justified either from the point of view of satisfying the population's basic necessities or of establishing a coherent production system.

5. New pattern of investment and finance

Since approximately the end of the 1960s, major non-ferrous transnationals have reduced their direct investment in developing countries. The spread of new patterns of investment accelerated since the mid-1970s with the appearance of new sources of finance. Commercial banks, export finance agencies, insurance companies and government funds from oil-producing countries increased their participation in the financing of non-ferrous metals projects.

The availability of those sources was linked to the oil crisis of 1973/74. Mineral and metal importers in Europe and Japan tried to stabilize the supply of minerals and metals by supporting investment in new sources. Commercial banks tried to invest in the Eurodollar pool which grew quickly from inputs of revenues from oil producing countries.

The gradual decrease in the share of direct investment of the TNCs was caused by the increase of the national interest and ownership by developing countries in the mining and processing of non-ferrous minerals. The developing countries increased their national control over the non-ferrous sector through various means, including imposition of government controls, increased taxation, the building-up of national competence and the partial or complete nationalization of foreign equity 15/.

In addition, there were initiatives taken by some TNCs for the conversion of fully-owned subsidiaries into joint ventures with national enterprises. In the copper industry, Kennecott in Chile was the first company to adopt a joint-venture approach. In 1976, Asarco sold out all its assets to the Mexican Government. Also in other cases, TNCs supplied only technology without participating in equity. One of the first cases of this kind was the Companhia Brazileira do Aluminio in Brazil.

In the 1980's, investors, commercial banks and TNCs, are not as interested in mining and processing projects as they were 10 years ago due to the continuous imbalance between supply and demand, caused, inter alia, by the global economic recession and by the lower intensity for the use of traditional metals in industrialized countries.

In the case of copper, for example, the investment level for projects under construction in developing countries decreased from a range that varies from US$5 billion to US$10 billion, in the late 1970s, to almost half that level in 1987 where it reached US$3 billion dollars. The capacity addition was unevenly distributed between the copper producing regions in developing countries. Investment was concentrated in Latin America while African producers were not able to keep their relative capacity levels and their smelter and refinery capacity even decreased in absolute figures. Projects under construction in African countries, in early 1980, were down to almost zero, but have since risen slowly. The African projects are mainly concentrated at the mining stage of the production chain.

15/ Radetzki, Marian "Has political risk scared mineral investment away from the deposits in developing countries?" World Development, Vol. 10, No. 1, 1982, pp.42-43.

Investment in the copper sector in Asian developing countries, declined in a similar way as in Africa, but throughout the decade remained at a higher level. Between 30 % to 40% of total investments were made in Asia, in the mid-1980s.

It can be pointed out that the size of copper projects in developing countries having become increasingly complex by the end of 1970, decreased during 1980, reflecting the change to rehabilitation rather than green field projects.

6. Sources for financing the non-ferrous metals sector in the 1980's

It is unlikely that the traditional sources of financial resources to the non-ferrous sector during 1970, would be prepared to continue furnishing financial resources in the future. Commercial banks have become less eager to participate in large, complex non-ferrous projects, particularly in developing countries [16/]. The role of transnational corporate investment is also likely to be far less significant than during 1970. For developing countries, the major sources of capital during late 1980 are: national private capital, internal sources generated by state enterprises, public international agencies, national development agencies, export credits and centrally planned economies [17/].

The importance of national capital in investment of non-ferrous projects is currently increasing. In developing countries, the national sources of foreign exchange are often very limited but local banks can supply local currency loans. This procedure is practised in non-ferrous industries in Zambia, Zaire and Mexico.

In carefully selected projects, financial resources generated by State mine enterprises can be a national source of finance. In early 1986, Codelco, the Chilean copper State enterprise, announced a five year investment programme (1987-1991), amounting to US$1,385 million. At the end of 1986, US$150 million was slashed from the programme by the Ministry of Finance. The internal fund is the most important source of long-term financing and also one which is subject to the greatest fluctuations. Any use of the internal funds has to be approved by the Ministry of Finance and thus depends on the country's macro-economic variables and government priorities.

Whilst the World Bank Group lending has declined, lending by bilateral funding agencies has increased. This trend reflects in particular the efforts made by Japan and the European countries to ensure a stable supply of minerals and metals through financial support to producers in developing countries.

16/ The share of commercial banks in financing of mining projects has declined to almost 50% since 1968 to 1986.

17/ S. Zorn. Financing Investments in Minerals in the 1980s, The Courier, No. 94, 1985.

From 1968 to 1986, the World Bank and the International Finance Corporation (IFC) participated in 27 major metals projects. The projects had a minimum individual size of US$50 million and an average size of US$230 million, with the exception of the single largest project of Carajas in Brazil [18/]. The copper industry received 26% of the total World Bank credits and the aluminium industry 10%. The lending pattern of the IFC exhibits similarities to the World Bank in that it is mainly concentrated in the copper industry in Latin America. IFC financed projects accounted for 16% of the increase in developing countries of the world copper mining capacity in 1970 and 18% of the increase between 1980 and 1983. IFC investment in the copper industry has practically ceased since 1980, and in 1984 IFC decided to concentrate on four types of project:

(a) Exploitation of relatively small mineral deposits of economic significance to local producers;

(b) Large projects in small countries to facilitate negotiations with foreign mining companies;

(c) Participation essentially as an equity investor to facilitate acceptable balance between local and foreign ownership and to provide an adequate base of risk capital;

(d) Participation in conjunction with government or public sector mining companies.

Due to its need for supplies of foreign resources, Japan has developed:

(a) import schemes with Japanese equity participation;

(b) concessionary loans in exchange for long term contracts.

The former type also includes a more comprehensive form of joint venture known as the Asahan formula, which was originally worked out to develop an aluminium smelter and the necessary power facilities in Sumatra, Indonesia. The venture, which was set up in the late 1970s, comprises both the Indonesian and Japanese Governments together with Japanese industrial partners. The Japanese EXIM bank also contributed to the project. Similar ventures have been set up in Brazil, i.e., the Amazon Aluminium smelter project including the Alunorte alumina joint venture.

The loan and import approach has been used by Japan particularly to secure copper and iron ores to Japanese smelters. In 1978, 50% of the copper ore imported was acquired under such schemes.

The Japanese EXIM bank has played an important role in financing these schemes, and in this respect is unique internationally [19/].

18/ M. Hang, Impact of International Lending on Metals, Arden House, 14 May 1986.

19/ T. Ozawa, Japan's largest financier of multinationalism. Journal of World Trade Law, Vol 20, No. 6.

The European Economic Community has two main windows for funding investments in the minerals industry, in primarily African, Caribbean and Pacific countries:

(a) The European Investment Bank (EIB);

(b) The Sysmin special financing facility for mining products under the Third Lome Convention.

The EIB has come to play a major role in the investment of the European Communities Commission in the mining and metallurgical industry in developing countries. In August 1985, EIB approved loans amounting to over ECU 240 million (European Currency Units) of which ECU 161 million went to West and Central Africa, ECU 57 million to East Africa, ECU 59 million to the Pacific and ECU 4 million to the Caribbean.

Originally the Sysmin focussed on maintaining production capacities. Under the Third Lome Convention, the main objective is to restore the viability of the mining industry through rehabilitation, maintenance and rationalization measures. The system also supports diversification measures. The financing funds of Sysmin have mainly been oriented to the copper industry in Africa. During 1980/81, Zambia received for its copper industry a loan of ECU 55 million and Zaire ECU 40 million [20/].

Some centrally-planned economies also finance mineral and metal projects. The Government of China, through its China International Trust and Investment Corporation (CITIC), joined the Portland Aluminium joint venture (Victoria State Government 35%, Alowa 45%, Public 10%) and agreed a 10% equity share in the project. When the smelter starts production in 1987, CITIC will reserve 15kt and this figure will rise to 30kt in 1988. The Chinese State organization, China National Non-Ferrous Industries Corporation (CNNC), has also been negotiating its participation in a foreign aluminium smelter with equity. They have approached Icelandic Aluminium to participate in the expansion of the ISAL smelter near Reykjavik in Iceland.

The USSR has participated in some projects related to bauxite and alumina. One of the the major projects realized is the Guinean State-owned OBK bauxite mine. The operation was started in the middle of 1970 and the entire project was financed by the USSR, with investment estimated at approximately US$100 million. 90% of the output is exported to the Soviet Union, 50% as repayment of the credits supplied, 40% are regular exports to the Soviet Union and 10% could be exported by Guinea on the world market. The USSR has also financed smelter and alumina works in India, Turkey, Egypt and Algeria.

In 1985, a new 2.3 million-tonne bauxite project in India was announced. The mine in Andhra Pradish would export most of its production to the USSR. The bauxite mine is to be supplemented by a 600kt alumina plant [21/]. Also a project between the USSR and Greece to produce alumina is being developed. The total investment is estimated at between US$450-500 million in a 600kt alumina plant to be situated in the Corinthian Gulf area. USSR loans will be repaid by delivery of alumina.

20/ The Courier No. 89 and 94, 1985.
21/ Engineering and Mining Journal, October 1985.

7. Final considerations

In the light of the considerations presented in this paper, it is particularly important for this meeting to devote its attention to the analysis of the possibilities of promoting strategies of a new kind that will enable this sector to make a greater contribution to economic and social development in developing countries producers of non-ferrous metals.

Among the aspects to be discussed, the meeting can focus on modalities to promote a more inward-oriented development of the non-ferrous metal industries at the national, subregional and regional levels, taking due consideration of the types of horizontal and vertical integration to establish, as well as the complementarities among countries. Another aspect in which the meeting can focus is the identification of adequate export policies for developing countries, in order to maximize their foreign exchange balance. This should be seen in the context of the difficulties that the producers of non-ferrous metals are presently experiencing due to the decline in prices and world consumption, and that several developing countries have good quality ore deposits and cheap energy which can be an important economic potential, and that when appropriate, should be used as a source of foreign currency to promote key sectors of the economy. Other aspect that might be considered important to discuss in the present situation is the identification of new fields for application of non-ferrous metals.

In this framework discussions could be concentrated on forms and means of co-operation between developed and developing countries and among developing countries themselves that can permit a more integrated development of this sector with other sectors of the economy as well as increase its impact on the major macro-economic variables of the economy.

This meeting may also be interested in the examination of the financial implications on the new forms of development of the non-ferrous sector as well as ways to improve the terms of financing. According to the present tendencies pointed out, the financing has to be oriented towards projects of adequate size, trying to obtain better conditions from the existing system; they could also increase the participation of the national and regional financing systems, and obtain better conditions for the financing of the infrastructure required by the project.

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Issue Paper II

TECHNOLOGICAL ALTERNATIVES IN THE NON-FERROUS METALS INDUSTRY*

Prepared by
the UNIDO Secretariat

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1. Introduction

It is obvious that the socio-economic conditions, the quality of the ores and availability of production inputs (e.g. energy, infrastructure, skilled labour, capital) is very different in developing countries from the relevant conditions in developed countries. Therefore, the technological options considered as being the more suitable for developed countries might not be the most advantageous for developing countries. This might particularly be the case when analysing the options related to the size of the plant.

The apparent advantages in constructing an optimum-size plant are often not realized in developing countries. Among the specific difficulties which often arise in large projects are the following:

(a) time of construction for large plants is usually longer, with higher costs and greater difficulties in arranging utilities, ancillary facilities and infrastructure than small plants;

(b) large plants tend to experience more technical operating problems than small plants, maintenance may be more problematic, and technological rigidities are more likely to occur;

(c) operating rates tend to be lower in large plants than in smaller units, thus increasing average fixed costs;

(d) great dependence, in general, on exports to the world market at a time of decrease or slow growth of world demand, as well as price deterioration;

(e) large plants present less flexibility in the process of integration of the non-ferrous metals sector with the other sectors of the economy at the national and regional levels.

(f) large plants demand important investment and financial resources, at a time in which many developing countries have debt problems.

The rapid technological change occuring in some mineral processing industries also has implications for developing countries' ability to establish processing facilities. Certain developments, such as the production by continuous casting of aluminium sheets and strips, permit the construction of plants on a much smaller scale than was previously thought economical, opening the way for processing for internal consumption in many developing countries.

On the other hand, new developments such as continuous casting in copper have the effect of making it more difficult for producers located at considerable distances from major markets to compete effectively.

There are however other aspects to be considered in the selection of a technology such as the quality of the ore, the price of the energy, the transportation costs and the possibilities of increasing the surplus of foreign currency to develop key sectors of the economy.

2. Existing and emerging new technologies in the non-ferrous industries 1/

According to their socio-economic conditions, developing countries should take full advantage of the technological improvements to make better use of their resources and attempt a more integrated development at the national and regional levels. In this context special emphasis has to be given to the analysis of technological alternatives for the fabrication of semis and finished products.

2.1 Production of non-ferrous metals up to refinery

From production up to refinery there are some technological developments that should be taken into account in order to improve the productivity of present installations or in new projects.

In order to decrease production costs, particularly energy costs, the conventional copper sulphide flow sheet has undergone significant changes since the 1970's: increasing the size in mining and milling equipment for economies of scale; introduction of column-flotation in the field of concentration for the separation of different minerals, basically in the copper industry and for by-product molybdenum recovery; and intensification of chemical, pyro-metallurgical processes by injection of oxygen through which reactions are speeded up, the capacity of furnaces increases and the products are obtained at a lower cost.

A particularly convenient technology has been developed for treatment of sulphide and oxide ores by hydro-metallurgical means, which avoids expensive traditional concentrating and smelting steps with all their impact on the environment. Several countries are interested in the improvement of the technology of processing polymetallic copper-containing ores.

The extraction of bauxite, its refining into alumina as well as the production of the metal by electrolysis are well established technologies. Although a steady improvement of these processes is taking place, fundamental changes are not expected before the end of this century. The new technological developments are aimed at decreasing the cost of energy as well as for a better exploitation of capital goods due to their increasing cost.

In the lead and zinc industries, which handle higher grade and more complex ores, but on a smaller scale than copper, significant improvements in technology are visible not so much in the concentrating stage, where classical technologies and flotation concentration are practically and conveniently adjusted to every specific ore and its metallurgical problems, but rather in the pyrometallurgical stage. Here, apart from specific processes for individual treatment of each metal, alternatives exist for a collective treatment of bulk concentrates to improve considerably overall metal recoveries and costs. The high complexity of these ores and significant difficulties in separation of individual metals by differential flotation, generally result in high metal losses. Thus, processes such as the Imperial Smelting and Sulphate Roasting Process attract increasing attention.

1/ Annex I presents the different technological alternatives for the non-ferrous metals.

New pyrometallurgical technologies also include the Sherritt Pressure Sulphuric Acid (PSA) leach process, the emerging Kivcet process from the USSR, the Outokumpu Process (OKP) from Finland, the QSL process from Germany, etc.

All these processes should be given due attention with the idea that even if not all individual developing countries are in a position to install their own plants, they can conveniently agree on some regional plants which will handle their combined production with a higher efficiency.

Tin is now experiencing difficult times in view of the collapse of the International Tin Council and the sharp drop in tin prices. One way to cope with these problems is to concentrate on more economically effective methods. In this respect, a relatively cheap and effective method of flotation for tin fines is brought to attention. Also, the fuming process has received increasing consideration because of its more effective possibilities to eliminate impurities and increase recoveries into final product.

In nickel the technological improvements are oriented towards increasing energy saving and the rate of metal recovery. In this respect special attention should be given by developing countries to the new developments that are emerging in the hydrometallurgical processes, in particular to the treatment of limonite-type lateritic ores with sulphuric acid.

2.2 Production of semis and finished products of aluminium and copper

The production of semis and finished products seems to be a key aspect for developing countries, due to the flexibility in the sizes of the plants and many possibilities to increase the horizontal integration at the national and regional levels.

Sizing of semi-production lines is a complex question. There are certain semi-products for which the transport is only economical within a very limited area. Fortunately, many semi-products can be produced in relatively small-sized plants. In the case of aluminium, this is typical for extruded products. Rolled aluminium products on the other hand are transportable even to long distances, but the size of their economic production is much larger. The size of economic rolling mills - including hot-rolling - is at least 40,000 tpy. Cold rolling mills could be of a smaller size than the hot ones. Cast-rolling units could be smaller, even 10,000 tpy units might be viable. Such production lines operate, however, advantageously in conjunction with a smelter, and the spectrum of the semis production with this type of equipment is narrower than with the usual rolling mills, and the fabrication of some high-alloyed aluminium products is not possible. It is ideal to have hot and cold rolling mills at the same place, otherwise an intermediate product has to be shipped to the cold mill, but it is also a common practice to set up cold mills processing coils.

In many developing countries there are great possibilities of producing finished products of non-ferrous metals. As examples we can mention wire and cable manufacturing, facilities producing kitchenware and other utensils, containers and certain non-ferrous products for the building industry.

Regarding the selection of main technological systems for the production of copper semis the following might be taken into consideration:

a) continuous casting processes, due to their low energy consumption and capital investment, decreased environment pollution, flexible production capacity, high productivity and high product quality;

b) wire rod production technology should be matched to the local or regional demand;

c) cold rolling mills equipped with hydraulic screwdown and automatic thickness regulation. Hot mills should be selected only for very high demand or special cases;

d) indirect presses offer a number of advantages, but at present horizontal direct presses are more flexible regarding the product mix. Having a suitable extrusion press, lower demand for wire rod can be temporarily covered by compromising on the size of the coils;

e) technological route for copper tube manufacturing should be selected on the basis of several factors. In a plant having free capacity on a cold rolling mill, welding tubes from strip and drawing them on skinner blocks could be a good solution. In the case of a plant having free capacity on the exisiting extrusion press, reduction on drawing benches can be a optimal solution offering a very wide product mix. One of the most efficient ways for the production of medium and small size tubes is the continuous casting - pilger rolling - spinner block drawing;

f) when establishing copper and copper-alloy or aluminium and aluminium alloy semifinished product manufacturing, special emphasis has to be put on recycling production and collected scrap. The better the scrap is separated the higher is its value. High economy can be achieved using every scrap for its proper purpose.

3. Main directions of research and development activities

In the context of the most promising areas for technological development in developing countries, the main lines of research seem to be those related to:

a) better use of polymetallic resources whenever appropriate with possible extraction of all useful components;

b) energy savings and the handling of materials in mining operations;

c) energy savings and processing efficiency increments in comminution operations, including semi-autogenous grinding and cyclone classification;

d) substantial improvements in flotation technology through greater volume flotation cells, introduction of new types of flotation cells, such as column cells, and improved reagent formulae;

e) greater use of hydrometallurgical, energy and capital saving technologies as reflected in bacterial leaching, solvent extraction and electrowinning technologies;

f) introduction of processes which perform conversion of the metal content of minerals, both of sulphide and non-sulphide character, into the metallic state with the lowest consumption of energy, as for example in the SX/EW and segregation processes;

g) improvement of the effectiveness of the Bayer alumina production technology through better adjustment of digestion and precipitation where appropriate, intensification of red-mud washing in order to reduce caustic consumption and produce a mud less harmful to the environment;

h) greater emphasis on byproduct recovery in all phases of base metals production, including flotation separation, hydrometallurgical, pyro-metallurgical and electrometallurgical separation. A number of important metals, such as gold, silver, molybdenum, cobalt, bismuth, selenium and rhenium, gallium and vanadium, can serve as valuable byproduct credits to reduce production costs of base metals. Also, non-metallic components such as sulphur and arsenic may be recovered at a profit;

i) organization of the processing and better valorization of intermediates. If appropriate, manufacturing of the following products, e.g.: artificial white bauxite; special aluminas; abrasive and refractory materials on alumina basis; different metal compounds sulphates, oxides, etc.; aluminium 99.99. Organization of collection, processing and use of recycled metals;

j) introduction of modern oxygen technology in base metals smelting in all its possible forms, with a clear aim towards optimization of results both economically and capacity-wise;

k) realisation of systematic cost reduction in the existing aluminium smelters through improved control of electrolyte composition, temperature, and cell operation;

l) possibilities of production of a broader spectrum of semis from aluminium and copper alloys through continuous casting;

m) reconstruction of existing rolling mills and equipping them with hydraulic screw-down system, electronic drive regulating circuits, automatic thickness and shape control and regulation;

n) confection of studies related with optimization of scale of operations for a determined process or technology, which can come from economy of scale or through miniaturization of plants more in accordance with national necessities and possibilities. Design of appropriate equipment, particularly for the production of semis;

o) systematic study of potential advantages for expansion of existing facilities through improved and intensified technologies versus construction of new plants.

Practical implementation of new technologies in the non-ferrous based metals area in developing countries will require a rather complex and imaginative combination of work at existing research facilities, universities and national research centres, along with work at industrial-type research organizations and engineering firms.

Several high-standard research and development institutions are operating in developing countries in the non-ferrous metals industries 2/. Their contribution can be relevant to the introduction of new technologies in the industrial practice; particularly the assessment of the viability of new processes and technology might be important.

4. Final considerations

The strategies of development as well as the financial constraints define in a certain way the main lines for the selection of the technologies.

Within the framework of the above and that which has been presented in this issue, it would be of special interest for the participants of this meeting to discuss, among others, the following:

a) technological improvements to increase the productivity of the existing production facilities of non-ferrous metal products. In this context, special emphasis should be given to the analysis of the possibilities of energy savings, broader application of hydro-metallurgy and processing of polymetallic ores;

b) technological alternatives for the production of semis and finished products by small and medium-size plants, which requires reasonable amounts of investment;

c) main lines of research and development to be implemented for the mastering of the non-ferrous technologies by producers in developing countries of non-ferrous metals products;

d) possible programmes of co-operation between developed and developing countries and among developing countries that could contribute to: the increase of productivity of existing facilities in developing countries; installation of new capacities for the production of semis and finished products; and the mastering of the non-ferrous metals technologies by developing countries.

2/ See Annex 2 where research and development activities in the field of non-ferrous metals in Latin America, Africa and Asia are presented.

Annex 1

CHARACTERISTICS OF THE MAIN TECHNOLOGICAL PROCESSES USED IN THE NON-FERROUS METALS INDUSTRIES

1. Aluminium

The extraction of bauxite, its refining into alumina as well as the production of the metal by electrolysis are well established technologies. Although a steady improvement of these processes is taking place, fundamental changes are not expected before the end of this century. Bauxite resources known at present will not be a limiting factor to further growth of the aluminium industry. The application of up-to-date methods of remote sensing might facilitate the identification of new ore deposits particularly in developing countries. Nevertheless the processing of low grade bauxites and non-bauxitic materials into aluminium might have local importance, because some countries may want to process their existing own raw material.

An energy-centric aspect dominates both in aluminium production and consumption, determining the development trend. This and the better exploitation of capital goods - due to their increasing cost - is the promoter of the development of the Bayer and Hall-Herault processes. Apart from the climatic factor there is no technical limitation to using these processes anywhere in their present or developed form, provided the erected facilities can be run and maintained in a given country, because when designing the plant a reasonable choice of automation and mechanization was made and the personnel was exposed to an appropriate training.

Due to environmental protection coming more and more into the fore, new aluminium smelters are of the pre-baked anode type using sandy alumina. This is the reason why new plants are based on the production of this type of alumina and some older ones - if not producing sandy - are transformed to produce this variety of alumina. Developing countries have mostly trihydrate type bauxite; the production of sandy alumina causes no problem with such raw material.

Size of units plays an important role in the economy of production. The size of an alumina plant has grown from 120,000-150,000 tpy to a line capacity of 300,000-500,000 tpy. Hence plant capacities often reach or surpass 1 million tpy. On the other hand, smelters nowadays are built with capacities of about 100,000 to 300,000 tpy, the actual capacity depending on the line capacity.

The development in semi-products' fabrication tends to be more dynamic. Although the basic production methods have been well-known for decades, the efficiency of these processes as well as the production of products with increased quality parameters lie steadily in the fore of recent development. Sizing of semi-production lines is a complex question. However in general they can operate economically at relatively small size plants.

Approximate optimum capacities for the large-scale manufacture of some selected finished items are dealt with in Table 1.

Capital expenditure can be compared to that of erecting a smelter. From a comparison of the corresponding figures it will be observed that specific investment costs for one tonne of finished product may greatly vary with the type of product under review, and may be as much as 5 to 6 times that of the ingot (in the case of kitchenware) or just a fraction thereof (in the case of furniture frames, ladders or scaffolding). One point, however, is especially significant: reasonable size capacities for these types of products can be found in the 500-5000 tpy range.

TABLE 1: ECONOMICALLY FEASIBLE MINIMUM SIZE OF FACILITIES AND THEIR INSTALLATION COSTS
(smelting = 100)

Plant	Processed metal per cent	Investment costs per cent
Aluminium smelter	100	100
Finished product manufacture		
Kitchenware	0.1	0.6
Cans	2.25	7.2
Liquid gas bottles	2.0	3.6
Casks	0.4	1
Radiators	0.75	1.1
Lamp posts	1.22	1.8
Stranded wire, uninsulated conductor	4.4	0.9
Cables, insulated conductors	10	6
Containers and tanks	1.2	2
Collapsible tubes and aerosol bottles	5	6.5
Sandwich panels for the building industry	0.7	0.6
Portals, small buildings	1.0	0.4
Furniture frame, ladder, scaffolding	0.8	0.2

2. Copper

Most copper today is processed by mining, waste leaching and cementation, concentrating, smelting, and refining. Open-pit mining is more common than underground mining and overburden or waste contains some copper. Frequently the waste is leached to extract the copper, which may be recovered by passing the leach solution through a bed of scrap iron, precipitating metallic copper, and dissolving the iron; the last operation is called cementation.

The copper ore from the mine, often containing less than 1% copper, is transported to the concentrator where it is first crushed and then ground with water. The ground ore slurry enters flotation cells, where copper concentrates are collected as a froth. Following dewatering, they enter the smelter. In the smelter the sulfide minerals react with oxygen and fluxes to produce impure copper metal, SO_2, and slag. Smelting occurs in two steps.

In the reverberatory furnace, the copper concentrate is melted to produce matte, the mixed sulfides of copper and iron. Next, air is blown through the matte in the converters, producing impure copper plus a slag containing the iron. The impure copper is then cast into anodes and purified by plating onto pure copper in an electrolytic tankhouse.

Other hydrometallurgical processes include the direct leaching of ore followed by recovery of copper by cementation or electrowinning. Recently, however, hydrometallurgical treatment of concentrates in lieu of smelting is being developed in order to avoid the high cost of environmental control facilities required for new smelters.

In order to decrease production, particularly energy costs, the conventional copper sulphide flowsheet consisting of crushing, grinding, flotation, dewatering, smelting and refining, underwent very significant changes since the mid seventies with the following main trend.

Escalation of size in mining and milling equipment to bring about reductions in operating and maintenance costs (the so-called economies of scale); intensification of chemical, pyrometallurgical processes by injection of oxygen, by which reactions were sped up and capacity of furnaces increased; replacement of expensive pyrometallurgical processes with high energy consumption by less expensive hydrometallurgical processes which promote chemical reactions at lower temperatures and with a more thorough treatment of materials.

In mining, technological improvements range from improved and more efficient explosives to more accurate and greater mobility drills. In mine ore handling systems, improvements have ranged from in-pit movable crushers to development of fleets of giant trucks and change to large tonnage transportation (away from trains and trucks) and huge conveyors.

Comminution operations account for over 50% of overall milling (crushing-grinding-classification-concentration-dewatering) costs. Classification operations generally include intermediate comminution operations after removal of material already reduced to a specified size.

In this respect, in the last two decades a fundamental change in classification technology has been taking place almost universally by replacing rake and bowl classifier technology with hydrocyclones. The tremendous advantages of hydrocylones are their effective classification and separation of fines, low consumption of spare parts, very small size of equipment, permitting to double grinding capacity under the same roof, and their easy adaptation to automatic controls of the grinding circuit.

Autogenous grinding is the grinding of ore by itself rather than by special metallic or nonmetallic grinding bodies distinct from the ore. However, autogenous grinding by itself is not always successful for crushing and grinding big chunks of rock, due to a deficiency in the rock media, or when frequent changes in quality of media occur. In this case in order to assure smooth operation, large steel grinding balls are added in quantities between 2% and 10% of the total volume. Currently, most of such semi-autogenous mills carry less than 5% by volume of such steel balls, while the traditional ball mills use a 45% by volume ball charge. In most porphyry copper operations today, which treat large tonnages between 20,000 and

150,000 tons per day, semi-autogenous mills replace secondary and tertiary crushing and the rod mill grinding stage.

In the area of concentration, a technologically new system for replacement of traditional flotation cells was developed recently in Canada. This is the so-called column flotation. The idea offers a number of advantages in the separation of different minerals, particularly in the copper industry and in the area of byproduct molybdenum recovery.

The principal characteristic of this column is that it has no moving parts, and solids are kept in suspension by rising bubbles alone.

Hydrometallurgy, in particular the leaching technology, proved to be a safe, efficient and cost effective method for a number of metals, which include copper, gold and uranium. These chemical processes can be carried out in a number of ways, starting with in situ leaching, when fragemented and fractured material is not excavated, or by the heap leaching method when the broken rock is dumped on specially prepared pads and sprinkled with leach liquors which are conveniently recirculated. Leaching can also be carried out at atmospheric pressure or in closed vessels at elevated temperature and pressure. It can be purely chemical, using acid, caustic soda or cyanide, or biological using particular strains of bacteria. The bacteria do not actually leach the materials but rather render them amenable to subsequent chemical leach by speeding up the oxidation of the sulphide minerals.

Leaching is a relatively cheap and simple technology, easy to introduce since it requires little in the way of sophisticated euqipment. Leach liquors obtained either by in situ, heap, vat or agitation leaching, are conducted for purification to a solvent extraction unit and then subjected to reduction to the metallic state by electrowinning (to copper cathode).

While sulphide ores can be cheaply leached by ferric solutions helped by bacterial leaching technology, with oxides treated by more conventional acid leaching, the new solvent extraction technology gives a possibility to effectively clean such solutions for their final electrowinning step to produce high-purity (99.9% Cu) cathode. This SX/EW technology is now highly popular in developed countries, such as the USA and Canada.

More than anywhere else, cost cutting technologies have spread in the pyrometallurgical area, where costs are high because of high energy consumption. One way to cut costs is to decrease the temperature of conversion of minerals into metal, such as is accomplished in the Segregation Process.

The other method is to intensify the process with oxygen injection, through which reactions are sped up, capacity of furnaces increases and products are obtained at a lower cost.

The most successful new smelting process is doubtlessly the Outokumpu Flash Smelting which combines roasting, melting and partial converting into a single process. When only preheated air (to 450°C) was used to supplement the heat generated by the exothermic oxidation of FeS, mattes assayed then only 45-50% Cu, and fuel oil needed to be added to finish the reaction. With the introcuction of oxygen enriched air, the process became completely autogenous and the copper content of the matte increased to 65-70%. With a higher grade of matte, the required converting capacity and energy consumption

fell sharply - by as much as 40 to 50 percent. Also, addition of oxygen reduces the volume of gases and increases their SO_2 content from the normal 10-15 percent to as much as 30 percent.

The flexibility of the flash smelting process in terms of treating concentrates of varying composition and controlling matte grade is based on the fact that the degree of oxidation in suspension (flash) smelting can be regulated rapidly and easily by changing the ration of concentrate to oxygen in the process air.

Among other up-to-date copper smelting technologies the El Teniente, Inco, Mitsubishi and Noranda processes should be mentioned.

3. Lead and zinc

The complexity of lead-zinc ores has led to numerous flowsheets for rational recovery of different metal components in the different ore combinations. The major types of ores so far have been lead-zinc-copper ores, lead-zinc ores, copper-zinc ores, and lead-copper ores. the overall recovery of metals in such complex ores, when calculated on their recoverable content into a finished concentrate, rarely exceeds 80 percent. These recoveries are even lower if sulphides are mixed with oxides. In fact, flotation recoveries do not present any difficulties as far as bulk flotation concentrates are concerned. Metal losses start principally in selective flotation.

Therefore, in the treatment of complex lead-zinc sulphide ores two new basic approaches have emerged in the last few years: one, which tries to start pyrometallurgical treatment of bulk concentrates right from the beginning without previous separation of individual concentrates, and the other, which improves technologies for teatment of the individual concentrates.

In the first case, excessive loss of metals in their flotation separation is avoided, and typically 90-95 percent metal recoveries are obtained against the average 80 percent recoveries by other classical methods. The most outstanding in this respect is the Imperial Smelting Process with 13 industrial installations to its credit so far offering an overall recovery of about 95 percent of the metals. However, in some cases the Imperial Smelting Process is not quite suitable for solving all problems, and new, chemical processes are being developed for the same purpose.

In the area of direct smelting of concentrates, like with copper, there are two types of new processes in development: those which use bath smelting, such as the Boliden Kaldo (TBRC) Process, and the QSL Process. The other group of direct smelting furnaces are the flash smelting technologies as developed by Outokumpu and Kivcet.

At any rate, it should be clear that these emerging technologies still have to be convincingly proven in full scale industrial plants.

4. Tin

Under the present conditions of the tin market economically more effective methods are particularly important for this industry. Among them the fuming process and an efficient method of flotation for tin fins merit special attention.

During the 1970's, an increasing proportion of lode tin was mined, due to the gradual exhaustion of sources of alluvial tin. It has become increasingly difficult to obtain high-grade tin concentrates at a high recovery from lode material. Rather than lose an increasing amount of tin by attempting to upgrade the concentrates, there has been a trend towards the fuming processes, which give a medium grade concentrate of 40-50 percent Sn at high recovery rates of over 90 percent. This compares with 50 percent or less recovery for obtaining concentrates of about 60 percent Sn by mineral processing methods.

Fuming, in favourable cases, may replace mineral processing altogether to produce a concentrate directly from the ore. But this certainly requires high-grade ores to start with. Fuming normally requires products of 7 percent Sn and more.

In an endeavour to recover more of the fine tin produced by ever finer grinding to liberate cassiterite, particularly if this is intimately associated with sulphide minerals, flotation has been widely introduced, not merely to float sulphides away from cassiterite concentrates, but also to float cassiterite from the gangue minerals. Although the production of this flotation concentrate can boost tin recovery significantly, by 20 percent and more, the product is very low-grade, around only 20 percent Sn, and calls for new methods of treatment.

5. Nickel

The treatments used to recover the nickel from sulfide and lateritic ores differ considerably because of the ores' different physcial characteristics. The sulfide ores, in which the nickel, iron, and copper occur in a physical mixture as distinct minerals, are amenable to initial concentration by mechanical methods, eg, flotation and magnetic separation. The lateritic ores are not susceptible to these physical processes of beneficiation and chemical means must be used to extract the nickel. There are two main types of lateritic ores: limonite and serpentine containing deposits.

Pyrometallurgical Processes. Sulfide ores first undergo crushing and milling operation to reduce the material to the necessary degree of fineness for separation. Froth flotation or magnetic separation processes separate the sulfides from the gangue. Most sulfide ores then undergo a series of pyrometallurgical processes consisting of roasting, smelting, and converting.

Nickel oxide ores can also be processed by pyrometallurgy, they are smelted with a sulfiding material, e.g. gypsum, to produce an iron-nickel matte, that can be treated similarly to the matte obtained from sulfide ores.

Both types of ore can be leached with ammonia. Lateritic, limonite type ores can also be leached with sulphuric acid. Because of possibilities of energy saving and rate of metal recovery this process seems to attract increasing interest. Serpentine-type lateritic ores are mainly used for ferro-nickel production. Among possible development of nickel production technology, are plasma-smelting for the direct extraction of the metal from the ores and the use of organic solvents for the separation of nickel from solutions.

Annex 2

RESEARCH AND DEVELOPMENT IN DEVELOPING COUNTRIES

Table 1. Research and Development in Latin America

Country	Name of the institution	Resources in million US$, 1985	Activities	Staff
Argentina	INTI	0.5	Extraction of Ni and Co.	14
Brazil	CEPED	13.0	Beneficiation, biological leaching of Cu ores. Review of environmental conditions in Cu mining and ore dressing. Development of Cu alloys for coin fabrication.	160
Brazil	CETEM	2.0	Pilot plant studies of Cu, Pb and Zn ore treatment. Processing of Sn ore fines. Cu and Ni minerals bulk flottation. Electrorefining of Cu with pulsating current.	149
Brazil	CTP	0.5	Environmental control in the Cu and Ni industries.	10
Brazil	IPT de S. Paulo	0.04	Extraction of Cu from complex oxidized ores.	2,600
Chile	CIMM	2.0	Cu ore dressing and metallurgy. Au processing methods for "small mines". Separation of Mo and As. Recovery of rutile from copper tails. Hydraulic transportation systems for solid materials.	300
Chile	INTEC	1.0	Heap leaching Cu-ores, of Au and Ag Gravitational concentration and tailing recovery Cu, Au, Co, W, etc.	72
Chile	INACAP	8.5	Training on process control and automation in the copper industry.	121
Chile	Sociedad Minera Pizarro Lida	n.a.	Exploration and beneficiation of Pb deposits. Alternative Al and Pb technologies. Pb alloying.	6
Chile	Universidad de Tarapaca	0.05	Non-destructive testing, standardization and quality control of metal products.	52
Colombia	CIDI	0.12	Recovery of Zn in an iron and steel plant.	15

Country	Name of the institution	Resources in million US$, 1985	Activities	Staff
Costa Rica	Instituto Tecnologico	0.04	Extraction of Al minerals. Recycling and refining of Al alloys.	8
Ecuador	Politecnica de Litoral	0.06	Al alloying. Scrap recycling and refining. Pure Ni electroforming Zn and Cu alloys.	7
Jamaica	Jamaica Bauxite Institute	n.a.	Improving the processability of Jamaican boehmitic and goethitic bauxites.	26
Mexico	Instituto Politecnico Nacional, Esiquie, Laboratorios pesados de Ingenieria Metalurgica	0.23	Leaching of concentrates of non-ferrous metals. Substructures produced at high temperatures. Optimization of flat rolling sequences.	50
Peru	INGENMET	1.708	Exploration and evaluation of deposits (Cu, Pb, Zn, Ag); (Sn, W, Au). Problems of underground mining, beneficiation of ores. Polymetallic minerals flottation. Bacteriological leaching of Cu minerals.	75
Trinidad and Tobago	Caribbean Industrial Research Institute	6.0	Experimental casting prototype development.	60

Source: Inventory of Research and Development institutions
UNIDO, Department of Industrial Promotion, INTIB, 1987

LIST OF ABBREVIATIONS

Research Institutes

CEPED	Centro de pesquisas e desenvolvimento
CETEM	Centro de Tecnologia Mineral
CTP	Centro de Tecnologia Promon
IPT	Instituto de pesquisas tecnologicas de Estado de Sao Paulo S/A
INTI	Centro de Investigación para las industrias minerales
CIMM	Centro de Investigación Minera y Metalurgica
INTEC	Comite de Investigaciones Technologicas de Corfo
INACAP	Instituto Nacional de Capacitacion Profesional
CIDI	Centro de Investigaciones para el desarrollo integral
INGENMET	Instituto Geologico Minero y Metalurgico
CMRDI	Central Metallurgical Research and Development Institute

Table 2. Research and Development in Africa

Country	Name of the institution	Resources in million US$, 1985	Activities	Staff
Egypt	ASSIUT University Department of Mining and Metallurgy	0.15	Production of Al-Ti, Al-Si alloys. Beneficiation of nepheline-cyanite. Recycling of materials in the Al industry.	28
Egypt	CMRDI	0.7	Activation of bentonites. Cryolite regeneration. Alloy and surface protection development. Cu refining. Pb recycling.	72
Egypt	TABBIN Institute for Metallurgical Studies	1.0	Production of high quality Al castings. Corrosin resistance of Al-alloy castings. Anodizing. Heat treatment of brasses.	50
Kenya	Kenya Industrial Research and Development Institute	0.98	Analysis of metal contamination in canned fruit and vegetable products.	45
Morocco	Direction de la Geologie	2.45	Exploration of deposits of non-ferrous metals. Investigations on precious metals associated with Cu and Pb.	300

Source: Directory of Research and Development Institutions. UNIDO. Department of Industrial Promotion. INTIB. 1987.

Table 3. Research and Development in Asia

Country	Name of the institution	Resources in million US$, 1985	Activities	Staff
China	General Research Institute for Non-Ferrous Metals	n.a.	Beneficiation of ores, process and quality and environmental control, alternative technologies, manufacture of Al and Cu products. Recycling.	1,200
China	Institute of Metal Research, Academia China	3.5	Development of Al- and Ni-based alloys, copper tubes and wire. Quality control in the production of Al and Ni.	1,200
China	Shenyang Aluminium and Magnesium Research Institute	n.a.	Exploration and beneficiation of diaspore bauxite. Surface mining. Engineering for Al industry including main and auxiliary utilities for processing.	900
India	College of Engineering, Department of Metallurgy PUNE	1.8	Ni-Ti shape memory alloys. Liquid forging of Al alloys. Al/Al and Al/Cu rollbonding.	12
India	Indian Institute of Science	0.9	Mechanical alloying of Ni, Cr, ThO_2; Al alloys containing Mn and Li. Al, Cu, Zn castings. Bacterial leaching of lean sulphide ores.	350
India	India Lead PVT Ltd.	0.0126	Improvement of refining process. Desilverization. Pb-Sc, Ca-Pb alloy.	15
Indonesia	Mineral Technology Development Center, Department of Mining and Energy	2.0	Beneficiation of fine and sulphide complex ores. Flotation of galena. Production of Al-sulphate. Scope stability study on primary Sn ore.	106
Republic of Korea	Korea Institute of Energy and Resources	0.14	Origin and exploration of non-ferrous metals deposits in the country.	10
Republic of Korea	Korea Institute of Machinery and Metals	19.0	Development of Ni-base super-alloy castings for gas turbine application.	620

Country	Name of the institution	Resources in million US$, 1985	Activities	Staff
Malaysia	Geological Survey Department	5.39	Mineral exploration and assessment.	127
Pakistan	Metal Industry and Development Centre	n.a.	Development of alloys of non-ferrous metals. Melting and casting processes. Moulding sands.	7
Pakistan	Minerals and Metallurgy Division PCSIR	n.a.	Substitution of imported minerals and mineral-based products. Beneficiation of antimonial Pb ores.	34
Philippines	Metals Industry Research and Development Centre	1.2	Al, Cu castings. Electroplating.	128
Thailand	The Metalworking and Machinery Industries Development Institute	n.a.	Colours of jewellery, centrifugal casting.	7
Thailand	Regional Centre of Mineral Resources	0.027	Exploration and beneficiation of Pb, Zn, Sn, Ni ores.	9

Source: Directory of Research and Development institutions
UNIDO, Department of Industrial Promotion INTIB, 1987